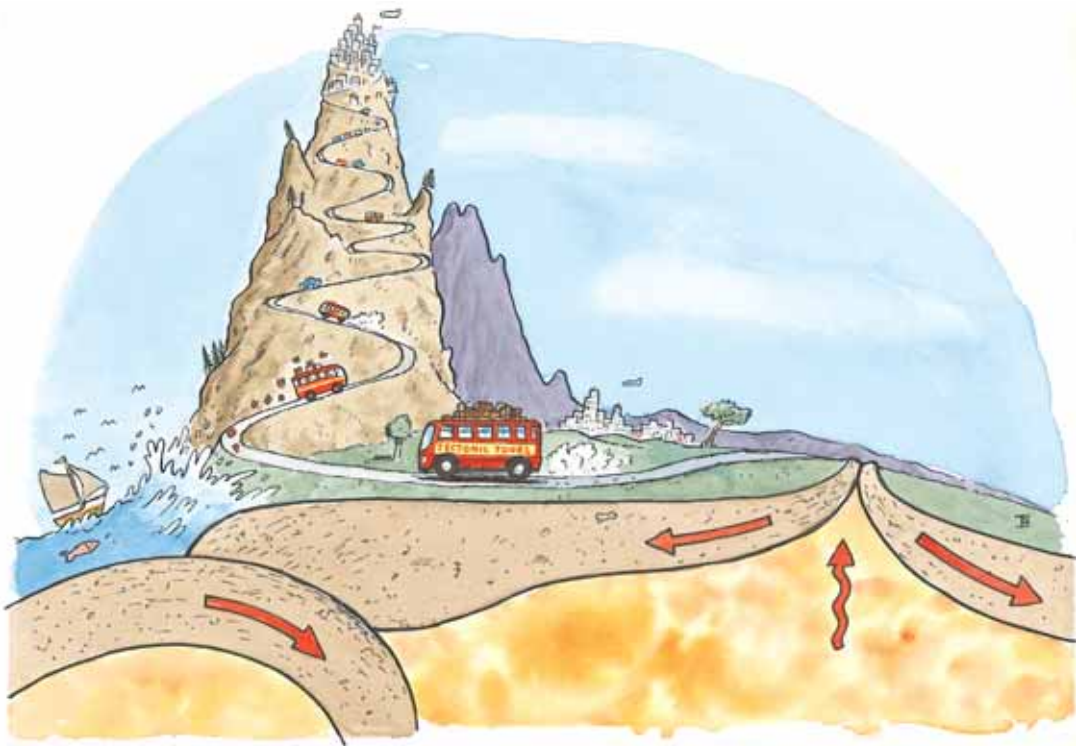




## Activity 2

# Plate Boundaries and Plate Interactions



### Goals

In this activity you will:

- Classify and label the types of movement at plate boundaries, using a world map that shows relative plate motion.
- Identify the distribution of plates by means of the world map of relative plate motions.
- Describe the present plate-tectonic setting of your community, and infer possible past plate-tectonic activity based on your knowledge.

### Think about It

New plates are created at certain places on Earth, and existing plates are consumed at certain other places. The total surface area of the Earth stays the same, so the creation of new plates has to be exactly equal to the consumption of existing plates.

- Where do you suppose you would have the most “interesting” ride on a plate? Would it be at the center, on a leading edge, on a trailing edge, or somewhere else on the plate?

What do you think? Record your ideas about this question in your *EarthComm* notebook. Include sketches as necessary. Be prepared to discuss your response with your small group and the class.

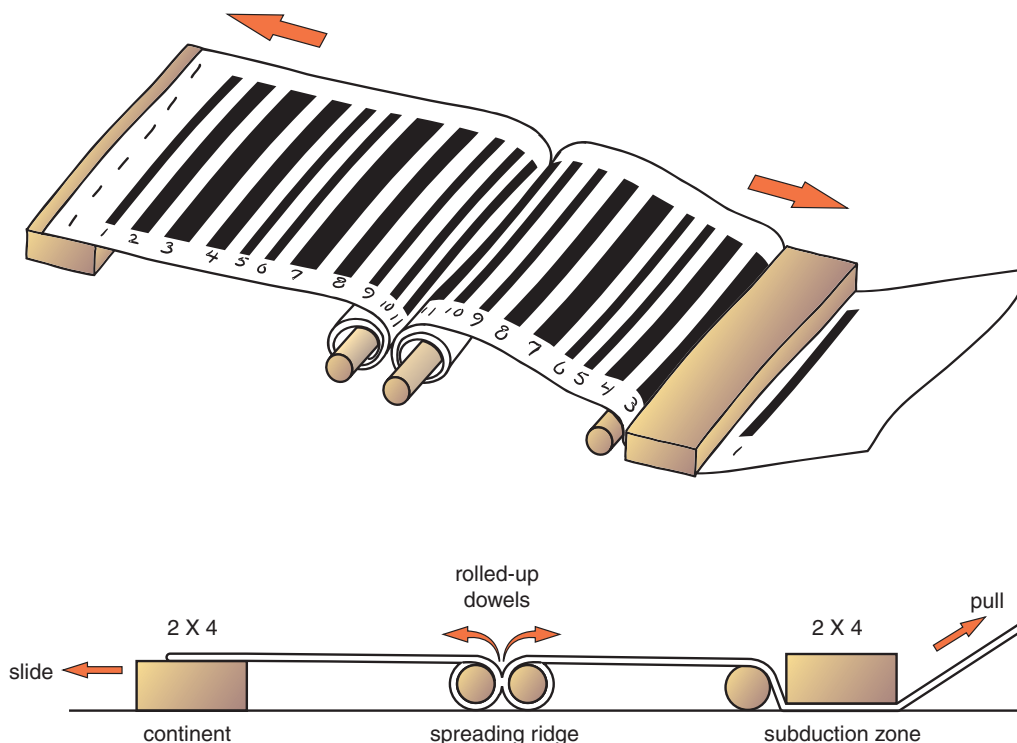
## Investigate

### Part A: Observing Plate Motions and Plate Interactions

1. Obtain the equipment shown in the following diagram.
2. Use the equipment to model a steady sea-floor spreading and subduction, as follows: One student holds the two rolled-up dowels in one place, loosely, so that they can turn but not shift their position. Another student holds the stapled piece of 2 x 4 lumber “continent” and pulls it away from the rolled-up dowels. A third student holds the dowel and piece of 2 x 4 lumber “subduction zone” at the other end loosely in place. A fourth student pulls the paper strip from under the piece of 2 x 4 lumber “subduction zone.” Be sure to unroll

the paper strips at the same rate, so that the numbers of the stripes stay matched up as they appear.

- a) What does the area at the rolled paper strips on the dowels represent?
- b) What does the section of paper between the dowels and the continental lithosphere (the piece of 2 x 4 lumber) represent?
- c) What happens to the length of this section of paper as the dowels are unrolled?
- d) As the dowels are unrolled, what happens to the width of the section of paper between the dowels and the subduction zone (the other piece of 2 x 4 lumber)?



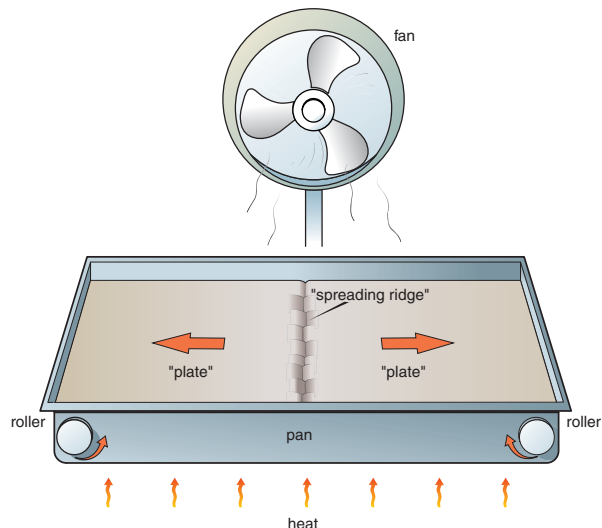


3. Use the equipment to model a collision of a spreading ridge and a subduction zone, as follows: Begin with the materials arranged in the same way at the end of **Step 1**. While two students pull the paper strips to unwind the two rolled-up dowels, the student holding those dowels slides them slowly toward the subduction zone. The student operating the subduction zone needs to make sure that the stripes appearing at the spreading ridge continue to have their numbers matched up.
  - a) What happens to the length of the strip of paper between the dowels and the “continent” side in this situation?
  - b) What happens to the length of the strip of paper between the dowels and the “subduction” zone?
  - c) At what “place” does the spreading ridge eventually arrive?
4. Think about the following questions, and write a brief answer to each in your notebook.
  - a) In the first part of the modeling (**Step 2**), how long will the ocean on the “subduction” side last?
  - b) In the second part of the modeling (**Step 3**), what do you think would happen in real life when the spreading ridge arrives at the subduction zone?
  - c) In the second part of the modeling (**Step 3**), how would the ocean on the “continent” side change after the spreading ridge arrives at the subduction zone?
  - d) In both cases, what do you think would happen in real life if the

continent became blocked in its movement away from the spreading ridge by something happening on the other side of the continent?

### Part B: How Transform Faults Are Formed

1. When the theory of plate tectonics was young, back in the 1970s, there was an experiment to see how divergent plate boundaries are formed. Scientists might describe this experiment as “beautiful” or “elegant.” It was small enough to be done on a table top. You can run it as a “thought experiment.” A diagram of the setup is shown below. Use a shallow square pan. Fill it with melted wax, and heat the bottom of the pan to keep the wax melted. Cool the surface of the wax with a fan, so that it crusts over to form “lithosphere.” Install roller cylinders along opposite edges of the top of the pan. These two rollers can be rotated outward in opposite directions to pull the solid surface of the wax apart.



- a) Predict what will happen to the crust of wax when the rollers are rotated. Assume that everything is adjusted right (composition of the wax; heating at the bottom; cooling at the top; speed of the rollers).
  - b) If a break were to occur in the surface wax, what do you think would happen to the liquid wax below?
2. In the actual experiment, the “lithosphere” broke along a crack across the middle of the pan. As the two “plates” on either side of the crack were formed, new “lithosphere” formed as the liquid wax welled up into the crack and solidified. The amazing thing about the experiment was that the original crack was formed with exactly the same pattern of ridge-crest segments and transform faults that can be seen in the real mid-ocean ridges!
- a) Were your predictions correct? How do you explain any differences between what happened and your predictions?
  - b) What does the experiment suggest about the age of the transform faults compared to the mid-ocean ridges?
- a) Name two plates that are moving toward each other (colliding/converging).
  - b) Name two plates that are moving apart (diverging).
  - c) Name two plates that are sliding past each other.
2. Use a blank world map to make a map that shows the three major types of plate boundaries.
- a) On the map, color the boundary line that separates two converging plates. Do not outline both of the plates completely; highlight only the boundary between the two plates.
  - b) Using two other colors, highlight the divergent plate boundaries, (where plates are moving away from one another) and the plate boundaries, where plates slide past one another (called transform boundaries). Make a key that shows this color code.

#### Part D: The Plate-Tectonic Setting of Your Community

1. Describe the plate-tectonic setting of your community. Refer to your world map and the map *This Dynamic Planet* (United States Geological Survey) in your work.
  - a) How far is your community from the nearest plate boundary?
  - b) What type of plate boundary is it?
  - c) How might your community change its position relative to plate boundaries in the future?

#### Part C: Plate Boundaries on World Maps

1. Look at the world map on page G66 in the previous activity, which shows the relative motion of the plates. Observe what it shows about how plates move relative to each other. Answer the following:



## Reflecting on the Activity and the Challenge

You have seen that plates can interact in three different ways: they can converge, diverge, or move parallel to each other. You have gained some experience in recognizing the three kinds of plate boundaries on world maps. You are better prepared for a later activity, on the different kinds of landforms that develop at the different kinds of plate boundaries,

and how earthquakes and volcanoes are caused at or near plate boundaries. You are now in a better position to help middle school students understand one of the key concepts of plate tectonics: the material of the ocean floors is always much younger than the oceans themselves!

### Geo Words

**divergent plate boundary:** a plate boundary where two plates move away from one another.

### Digging Deeper

#### THE DYNAMICS OF PLATE BOUNDARIES

##### Types of Plate Boundaries

Plate boundaries are geologically interesting areas because they are where the action is! Geologists use three descriptive terms to classify the boundaries between plates: 1) divergent boundaries are where two plates move away from each other; 2) convergent boundaries are where two plates move toward each other; and 3) transform boundaries are where two plates slide parallel to each other.

##### Divergent Plate Boundaries

You have already learned some things about **divergent plate boundaries** in Activity 1, because mid-ocean ridges are divergent plate boundaries. The mid-ocean ridges are places where mantle asthenosphere rises slowly upward. As it rises, some of the rock melts to form magma. Why does melting happen there? To understand that, you need to know that the melting temperature of rock decreases as the pressure on the rock decreases. As the mantle rock rises, its temperature stays about the same, because cooling takes a long time. However, the pressure from the overlying rock is less, so some of the rock melts. The magma then rises up, because it is less dense than the rock. It forms volcanoes in the central valley of the mid-ocean ridge. Geoscientists in deep-diving submersibles can watch these undersea volcanoes! Because of the great water pressure in the deep ocean, and also the cooling effect of the water, these volcanoes behave differently from volcanoes on land. The lava oozes out of cracks in the rocks, like toothpaste out of a tube. Some of the magma stays below the sea floor and crystallizes into rock there. All of these new igneous rocks, at the sea floor



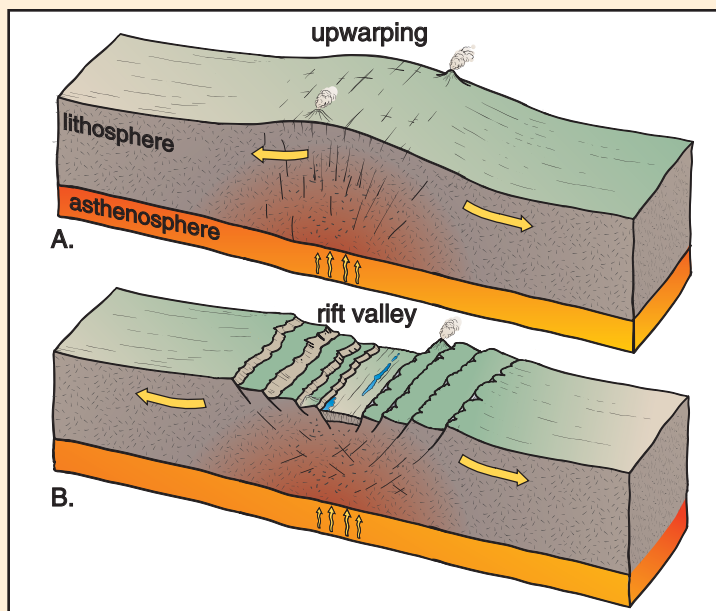
and below, make new oceanic crust, which then moves away from the ridge crest. This would be a good time to go back to **Activity 1** and review the material on sea-floor spreading.

In the investigation you modeled how the “continent” moved farther and farther from the “spreading ridge.” Look back again at the world map of lithospheric plates in Activity 1. In both the North Atlantic Ocean and the South Atlantic Ocean, there is no plate boundary along the coastlines on either side of the ocean. That tells you that the Atlantic Ocean is getting wider as time goes on. Why? Because new lithosphere is being created all the time at the mid-ocean ridge but is not being consumed at the edges of the continents. Does that make you wonder what would happen if you could make time run backward and watch the ocean shrink? At some time in the past, there was no Atlantic Ocean!

A new ocean begins when hot mantle material begins to move upward beneath a continent. Geoscientists are still not certain about why that happens. The lithosphere of the continent bulges upward and is stretched sideways. Eventually it breaks along a long crack, called a rift. See *Figure 1* for what a newly formed **rift valley** looks like. Magma rises up to feed volcanoes in the rift. As the rift widens, the ocean invades the rift. A new ocean basin has now been formed, and it gets wider as time goes on.

### Geo Words

**rift valley:** a large, long valley on a continent, formed where the continent is pulled apart by forces produced when mantle material rises up beneath the continent.



**Figure 1** The formation of a rift valley on a newly rifted continent.





### Geo Words

**convergent plate boundary:** a plate boundary where two plates move toward one another.

**subduction:** the movement of one plate downward into the mantle beneath the edge of the other plate at a convergent plate boundary. The downgoing plate always is oceanic lithosphere. The plate that stays at the surface can have either oceanic lithosphere or continental lithosphere.

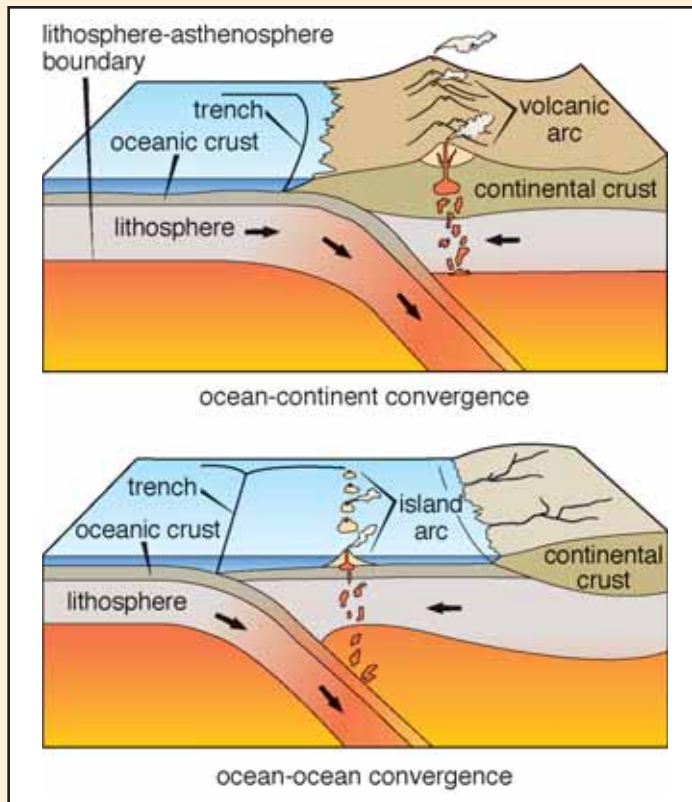
### Convergent Plate Boundaries

At a **convergent plate boundary**, two plates are moving toward each other. Your common sense tells you that one of them has to go under the other. (Would it surprise you to hear that common sense is important to a scientist, even though sometimes common sense can fool you?) There are three kinds of places where this happens. These are described below. In a later activity you will learn much more about the landforms that are produced at convergent plate boundaries, and how earthquakes and volcanoes are associated with convergent plate boundaries.

In some places, two oceanic lithospheric plates are converging. There are good examples along the western edge of the Pacific Ocean. Look back at the world map of lithospheric plates in Activity 1. The Pacific Plate and the Indo-Australian Plate are moving toward one another in the South Pacific, and the Pacific Plate and the Philippine Plate are moving toward one another in the Western Pacific. Look at the lower part of *Figure 2*. One plate stays at the surface, and the other plate dives down beneath it at some angle. This process is called **subduction**, and so these plate boundaries are called subduction zones. Where the downgoing plate first bends downward, a deep trench is formed on the ocean floor. These trenches are where the very deepest ocean depths are found. As the plate goes down into the mantle asthenosphere, magma is produced at a certain depth. The magma rises up to the ocean floor to form a chain of volcanic islands, called a volcanic island arc.

Other subduction zones are located at the edges of continents. Look at the upper part of *Figure 2*. The west coast of South America, where the Nazca Plate and the South American Plate are converging, is a good example. In places like this, the downgoing plate is always oceanic lithosphere and the plate that remains at the surface is always continental lithosphere. That's because the continental lithosphere is less dense than the oceanic lithosphere. Ocean–continent subduction is similar in many ways to ocean–ocean subduction, except that the volcanic arc is built at the edge of the continent, rather than in the ocean. The Andes mountain range in western South America is an example of a continental volcanic arc.

The third kind of convergent boundary is where two continental lithospheric plates have collided with each other. Think back to the investigation. You were asked what would happen when the “spreading ridge” arrives at the “subduction zone.” If you suspected that the spreading ridge would go down the subduction zone, never to be seen again, you were right! If you had continued the investigation after the spreading ridge had disappeared, what would have happened? As the plate that was on the other side of the



**Figure 2** Cross sections through subduction zones. The upper cross section shows subduction of an oceanic lithospheric plate beneath a continental lithospheric plate (ocean–continent subduction). The lower cross section shows subduction of an oceanic lithospheric plate beneath another oceanic lithospheric plate (ocean–ocean subduction).

spreading ridge was consumed down the subduction zone, the continent on the other side of the ocean would have moved closer and closer to the subduction zone. This is how two continents can come together at a subduction zone. Remember that continental lithosphere is much less dense than the mantle, so continental lithosphere cannot be subducted. The subduction stops! The continent that was coming along toward the subduction zone keeps working its way under the other continent, for hundreds of kilometers, until finally the friction between the two continents is so great that plate movement stops. The zone where two continents have met and become welded into a single continent is called a **suture zone**. There is only one good example on today's Earth: the Indian Plate has collided with the Eurasian Plate and is still working its way under it. ➔

### Geo Words

**suture zone:** the zone on the Earth's surface where two continents have collided and have been welded together to form a single continent.



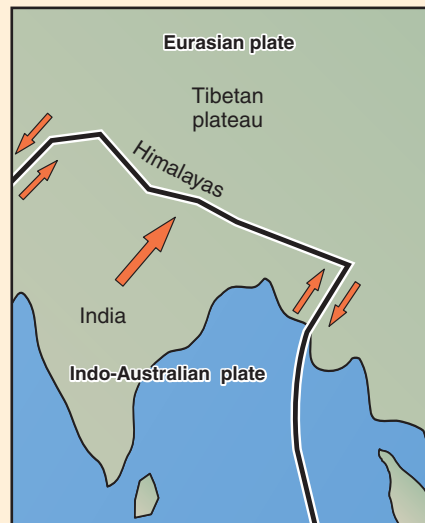


### Geo Words

**transform plate boundary:** a plate boundary where two plates slide parallel to one another.

**transform fault:** a vertical surface of slippage between two lithospheric plates along an offset between two segments of a spreading ridge.

See Figure 3. There is a good reason why the Tibetan Plateau is the largest area of very high elevations in the world: the continental lithosphere is much thicker there because one continent has moved under another.



**Figure 3** The Himalayas and the Tibetan Plateau were formed by the collision of the Indian Plate with the Eurasian Plate. The Indian Plate is being shoved horizontally underneath the Eurasian Plate, so the continental crust in the Himalayas and the Tibetan Plateau is much thicker than normal.

### Transform Plate Boundaries

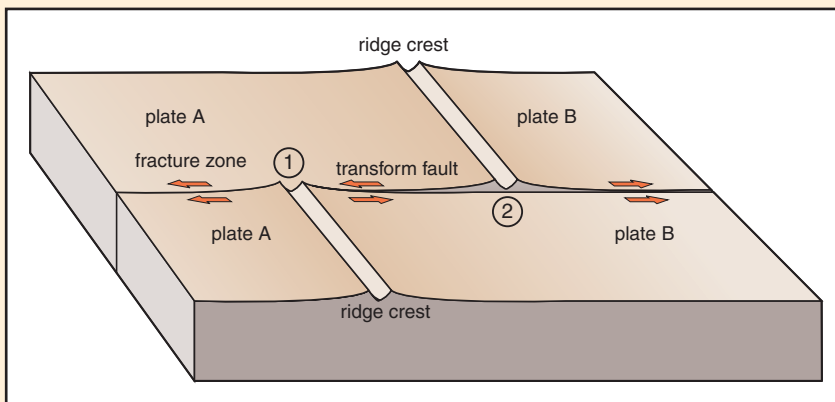
At **transform boundaries**, plates slide past one another. The surface along which the plates slide is called a **transform fault**. As you saw in Activity 1 in the material about mid-ocean ridges, transform faults connect the offsets along mid-ocean spreading ridges. Most are short, but a few are very long. The most famous transform fault forms the boundary between the North American Plate and the Pacific Plate, in California. It is several hundred kilometers long. You can see from the map in Figure 4 that the San Andreas Fault connects short segments of spreading ridges at its northern and southern ends.

The movement along the transform fault is limited to the distance between the two segments of ridge crest. Figure 5 is a sketch map of a mid-ocean ridge, showing segments of the ridge crest offset by transform faults. Between Points 1 and 2, Plates A and B are sliding past each other.

The transform fault extends only between Points 1 and 2. To the left of Point 1, Plate A is in contact with itself along the east-west line, and to the right of Point 2, Plate B is in contact with itself along the east-west line. Since the plates are rigid, there is no slipping movement along the east-west lines, which are like “dead” transform faults!



**Figure 4** Plates showing a transform boundary.



**Figure 5** Sketch map of a mid-ocean ridge, showing segments of the ridge crest offset by transform faults.

## Check Your Understanding

1. Name the three types of boundaries between lithospheric plates.
2. How and where are rift valleys formed?
3. How can ocean basins change in size?
4. Convergent plate boundaries can be in three different settings. What are they?
5. Describe subduction.
6. Why is it that transform faults can be used to figure out the directions of plate movements? Why can't subduction zones also be used for that?
7. What happens when two continents collide along a convergent plate boundary?



## Understanding and Applying What You Have Learned

1. Design an investigation, with the materials like the ones you used in this activity, to model the creation of a new ocean basin.
2. Identify on a world map of lithospheric plates one example of each of the following settings:
  - a) an established divergent boundary;
  - b) a young divergent zone (continental rift zone);
  - c) an ocean–ocean convergent boundary;
  - d) an ocean–continent convergent boundary;
  - e) a continent–continent collision zone;
  - f) the interior of a plate;
  - g) a transform plate boundary;

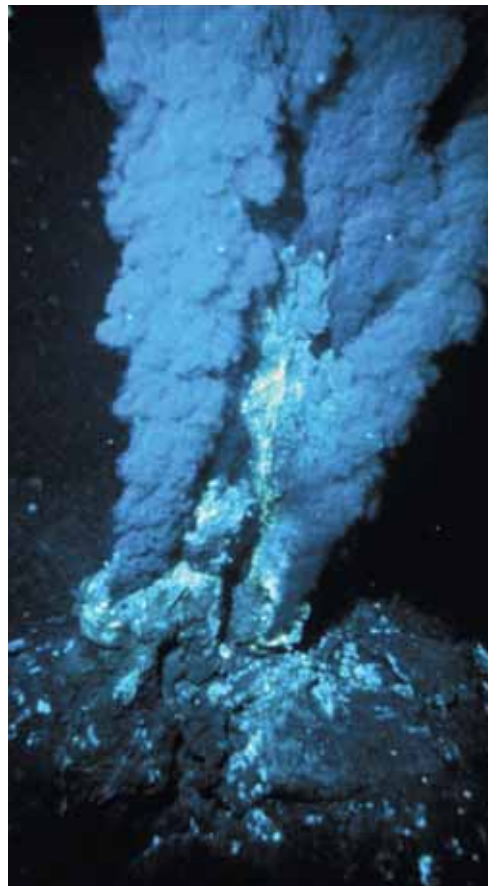
## Preparing for the Chapter Challenge

Reflect on your answers to the above. Write a short summary (one or two paragraphs) describing what you have learned so far about how plate movements and their interactions at plate boundaries can change the arrangement of continents and ocean basins on the Earth. Be prepared to include this summary in your **Chapter Challenge**.

## Inquiring Further

1. **Evolution of the Biosphere at Mid-Ocean Ridges**

Recently, new forms of life have been discovered at mid-ocean ridges. They thrive in the presence of superheated, mineral-rich water. This life does not depend upon the Sun for energy, but instead upon the energy and matter from Earth's interior. How has life evolved in such environments? For further information check the *EarthComm* web site.



Black smokers form at the mid-ocean ridges.